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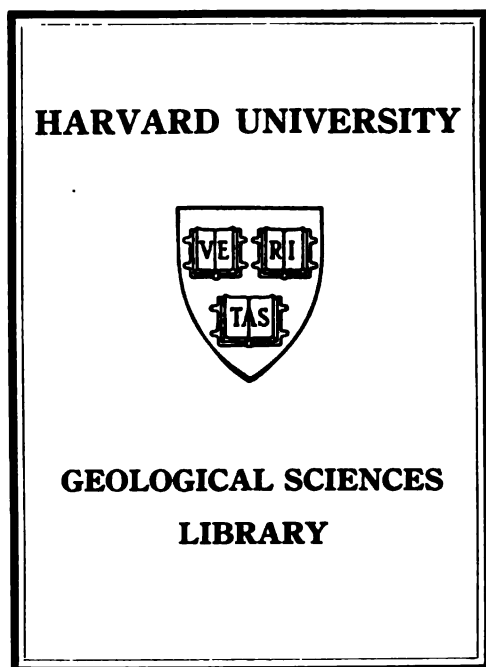
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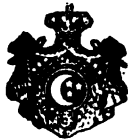
ON THE

SOIL AND WATER OF THE WADI TUMILAT LANDS

UNDER RECLAMATION

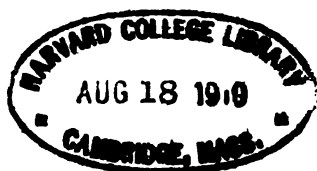
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A REPORT

ON THE

SOIL AND WATER OF THE WADI TUMILAT LANDS UNDER RECLAMATION

SITUATION.

THE Wadi Tumilat is a long narrow strip of land extending almost due east and west between the cultivation of the Nile delta near Abbassa and Lake Timsah at Ismailia. The valley is bounded on both the north and the south by desert.

CLIMATE.

No meteorological observations have been taken in the Wadi Tumilat itself, but the climate is a typical Egyptian desert climate characterized by abundant sunshine, high temperature during the day, relative low temperature at night and a very small annual rainfall.

The following figures will serve to convey an approximate idea of the general climatic conditions. Table I gives the results of observations taken at Ismailia, while Tables II, III and IV are from observations made at the Observatory near Cairo.

TABLE I.—ISMAILIA.¹

ANNÉE 1896	Température moyenne.					Humidité relative.			Pluie.	
	7 h. 30	14 h.	17 h.	Minimum	Maximum	7 h. 30	14 h.	17 h.	Hauteur en millimètres.	Nombre de jours.
Janvier ...	9·81	17·43	14·76	8·40	18·56	82·2	48·9	56·4	6·9	12
Février ...	10·73	19·74	17·39	8·92	21·00	81·1	42·0	49·3	4·0	8
Mars ...	13·73	22·17	19·84	10·80	23·43	77·7	39·4	43·3	6·1	9
Avril ...	16·01	25·97	23·01	12·57	26·71	71·3	32·3	38·2	1·2	4
Mai ...	20·42	30·17	26·16	17·41	31·69	63·8	28·3	41·6	2·7	5
Juin ...	21·55	32·50	28·40	18·10	33·84	80·1	30·9	41·8	0·0	0
Juillet ...	23·49	35·33	31·42	21·29	35·92	85·6	28·8	44·1	0·0	0
Août ...	24·39	35·53	31·66	22·31	36·27	85·2	34·2	43·6	0·0	0
Septembre ...	22·92	32·52	29·46	19·52	33·54	80·5	38·7	50·2	0·0	0
Octobre ...	20·01	30·16	26·25	17·43	31·02	..	..	..	..	..
Novembre...	15·50	26·26	22·51	13·37	27·22	86·7	39·4	52·4	0·0	2
Décembre ...	11·89	22·46	18·71	10·18	23·34	83·8	50·1	61·6	2·8	4
	17·54	27·52	24·13	15·02	28·54	..	..	..	..	..

¹ Annales du Bureau central météorologique de France, Paris 1898, année 1896, t. II, Observations.

TABLE II.—CAIRO.¹

Temperature.—Monthly Absolute Maxima and Minima for 15 years, 1894-1898.

MONTH.	Absolute.	
	Maximum.	Minimum.
	C	C
January	26·6	—0·7
February	35·3	1·2
March	41·2	3·2
April... ..	42·6	5·7
May	44·2	9·0
June	45·2	13·7
July	44·3	17·4
August	41·6	16·5
September	40·6	14·0
October	42·1	12·1
November	33·6	3·5
December	29·4	1·3
Extreme values	45·2	—0·7

TABLE III.—CAIRO.¹

Rainfall in Millimetres for 12 years, 1887-1898.

MONTH.	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	Mean.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
January ...	6·35	3·85	3·50	23·50	8·85	1·15	6·00	1·00	..	15·85	0·70	7·50	6·52
February ...	8·25	4·40	1·50	1·25	2·75	0·90	1·20	8·25	0·10	4·25	2·70	..	2·96
March ...	1·60	..	..	21·10	6·25	0·20	12·35	3·45	..	2·20	0·30	8·40	4·65
April... ..	0·45	6·25	0·10	0·10	..	0·60	..	..	14·70	2·30	..	..	2·04
May ... ..	..	12·60	..	..	..	0·10	..	1·10	1·40	3·50	0·10	..	1·57
June ... ..	..	1·15	..	..	..	..	..	..	..	..	..	..	0·09
July ... ..	..	..	..	..	..	..	..	..	..	..	..	..	..
August ...	..	..	..	..	..	..	..	..	..	..	..	..	..
September .	..	..	0·20	..	0·05	0·15	0·25	0·05	..	..	0·10	..	0·07
October ...	0·05	..	0·40	..	6·10	0·15	0·10	0·15	..	..	..	..	0·58
November..	..	10·80	1·25	3·00	0·05	1·20	3·80	2·50	26·90	..	0·70	22·70	6·08
December..	5·20	4·80	9·45	5·50	16·55	2·30	9·15	0·10	0·10	8·30	3·00	2·25	5·56
	21·90	43·85	16·40	54·45	40·60	6·75	32·85	16·60	43·20	36·40	7·60	40·85	30·12

¹ Report on the Meteorological Observations made at the Abbassia Observatory, Cairo." Survey Department, P.W.M., 1900, pp. 23 and 36.

TABLE IV.—CAIRO.¹

Evaporation, 1902.

MONTH.	Evaporation in millimetres.
	mm.
January	33·3
February... ..	59·9
March	99·9
April	148·6
May	249·6
June... ..	192·6
July	161·4
August	176·7
September	130·0
October	139·2
November	74·7
December	54·8

GEOLOGY.

²“The peninsula of Suez is composed exclusively in its whole breadth from Port Said to Suez, and in the whole thickness displayed in the canal cuttings, of young alluvial and quaternary deposits, these being disposed in such a manner that the centre of the isthmus (from near El Gisir to about half the length of the Bitter Lakes) is taken up by fluvatile fresh-water formations, which to the south pass step by step into the marine beds of the Red Sea, and to the north into those of the Mediterranean. Of fresh-water fossils, casts of *Melania tuberculata*, small *Bithynia* and *Planorbis* have been found on the rise of Gisir; beds of *Etherina semilunata* and in greater quantity *Spatha rubens*, *Vivipara unicolor*, *Bithynia bulimoides*, *Physa contorta*, etc., in the neighbourhood of Ramses, two hours eastward of Ismailia, and in the neighbourhood of Serapeum, *Etherina semilunata*, *Anodonta rubens*, *Bithynia bulimoides*, which are identical with species now living in the Nile. These facts led Capt. Vassel and also Fuchs to arrive at the conclusion that in Diluvial times a stronger arm of the Nile opened in the centre of the present Isthmus into the sea, and with its great mass of fresh water so filled the very narrow and shallow narrowing of the sea that it produced a wall of separation between the two seas, or

¹ Figures supplied by the Superintendent of the Observatory, Cairo.

² “Die Durchfluthung des Isthmus von Suez,” by Dr. C. Fr. Krukenberg, 1888, pp. 28 and 29.

better, between the faunas of both seas, inasmuch as these were unable to pass the sweet water of the Nile Delta, which closed the narrowing of the sea."

EARLY HISTORY.

The Wadi Tumilat formed part of the land of Goshen granted to Jacob and his sons about 1720 B.C. by the ruling Pharaoh, who then described it as being "the best of the land."¹

This description of the district was doubtless however from a shepherd's point of view. ²"In those days probably an overflow channel from the Nile inundated the valley annually during the flood and afterwards drained the lands into Lake Timsah on the waters subsiding. The flooded lands no doubt as soon as the waters retired grew green with fine pasturage, and held in their lowest hollows lakes of sweet water for cattle to drink. So that for Jacob's sons, who were shepherds, the valley was 'the best of the land.'"

³"The extensive deposits of Nile mud in the Wadi Tumilat prove the flow in ancient times of a considerable branch of the Nile eastward into the Red Sea. But a very slight elevation or silting up of the Red Sea would obstruct this arm of the Nile and impair the water communication and the fertility of the district. Of such results we have no evidence till the reign of Seti I, some time before the Exodus, when it became necessary to cut a canal through the Wadi Tumilat, and this canal had to be reopened and extended to the southward by successive rulers down to the Roman Period as the difficulty of maintaining it increased."

"This ancient canal, beginning at Bubastis, watered the land of Goshen with its branches and, entering the Bitter Lakes, changed their character, according to Strabo, and connected them with the Red Sea. From the not inconsiderable remains of the old canal near Belbès it appears to have been about 50 yards (100 ells according to Strabo) in width, and 16 to 17½ feet in depth. The somewhat steep banks are still strengthened at places with solid masonry. According to Herodotus the canal was four days' journey, and according to Pliny 62 Roman miles in length. In ancient times the canal was primarily constructed for purposes of navigation."

¹ Genesis XLVII, verses 6 and 11.

² Major Sir R. Hanbury Brown, *Public Works Ministry Report*, 1899, page 188.

³ "Egypt and Syria," 1892, Sir J. W. Dawson, F.R.S., page 69.

⁴ "Egypt." Baedeker, 1892, page 163.

Some sections of this Pharaonic canal were utilized during the making of the Ismailia Canal, of which they now form a part, and one portion near Kassassin now serves as a section of the main drain.

¹ In 1899 three kilometres which had been in use for irrigation were replaced by new channels.

² In 1901 a further length of "17 kilometres of the old stagnant reed-choked Wadi Canal" was suppressed.

In addition many dry and partly filled up portions exist and may still be traced.

PRESENT CONDITION.

The Wadi Tumulat may be divided into three sections: first, that portion situated round Abbassa and between Abbassa and Kassassin on the south side of the Ismailia Canal, and known as the Wadi Taftish or Wadi Estate; second, that part of the valley lying north of the Ismailia Canal between Abbassa and Kassassin; and third, the entire width of the valley between Kassassin and Ismailia.

Two main waterways traverse the valley from Abbassa to Lake Timsah, one being the Ismailia Canal which conveys water from the Nile near Cairo to Ismailia, and thence by branches to Port Said and Suez, and the other the central drain running almost parallel to it. "The lands have a mean height of 5·25 metres above low water in the Mediterranean and 5·99 metres above the lowest known sea at Suez, or 5·13 metres above the highest tide at Pelusium and 2·83 metres above the highest tide known at Suez."³

The maximum level now cultivated is R.L. 9·0. The water level at Kassassin is 8·50 and at Abbassa 9·20.⁴

About the middle of the valley, south of the Ismailia Canal, is Lake Mahsama; in 1902 the water-level of this lake varied from 5·18 to 5·60 metres above sea level.⁵

The several sections of the Wadi may now be described in detail.

1. THE WADI ESTATE.

In Mohammed Ali's time (1806 to 1849) the total area of this Estate was 21,918 feddans⁶ of which rather less than a third appears to have been cultivated.

¹ *Public Works Ministry Report*, 1899, p. 191.

² *Public Works Ministry Report*, 1901, p. 216.

³ "Mémoires sur les Principaux Travaux d'utilité publique en Égypte," by Linant de Bellefonds Bey, 1872-3, p. 102.

⁴ Figures supplied by the Inspector 1st Circle of Irrigation.

⁵ Figures supplied by the 1st Circle of Irrigation.

⁶ A feddan = 1·038 acre.

¹ In 1861 the Estate was purchased by de Lesseps on behalf of the Suez Canal Company. At this time about 6,000 feddans were under cultivation. After the construction of the Ismailia Canal the Estate was resold to the Khedive Ismail, and in 1865 he made it over to the Ministry of Public Instruction. In 1866 the cultivated area was 12,000 feddans.

² In 1891 the Estate was surveyed and the area found to be as follows:—

	Feddans.
Cultivable land leased	7,560
Cultivable if reclaimed, but uncultivated	9,972
Occupied by canals and uncultivable wastes	3,007
Total... ..	<u>20,539</u>

In March, 1899, the Estate was placed for a period of eleven years under the direction of the Ministry for Public Works, in order that a reclamation scheme might be carried out.

At present about two-thirds of the Estate are under cultivation, the various prizes gained at the Cairo Agricultural Show for Samar,³ Rice, Maize, Sesame, Cotton, etc., bearing witness to the general excellence of the crops.⁴ "At the Agricultural Show the Estate had eight exhibits and obtained seven awards, including a first prize for "Samar" mats, and a bronze medal for Cotton."

In parts, however, more particularly near the Ismailia Canal and at the sides of the main drain, there are areas still waiting reclamation, and here and there among the cultivation are bare patches covered with efflorescent salts.

Many of the fields bearing crops show more or less signs of efflorescence, and in the some places the crops are manifestly poor and stunted. Much efflorescence is visible too at the sides of many of the drains.

¹ *Public Works Ministry Report*, 1899, p. 186.

² *Public Works Ministry Report*, 1899, p. 191.

³ Samar, *Cyperus lævigatus*, a kind of sedge very resistant to alkali.

⁴ *Public Works Ministry Report*, 1901, p. 217.



Sur, Dept. P.W.M.

Several samples of the soil and of the efflorescences have been examined for injurious salts with the following results:—

TABLE V.—SOIL SAMPLES.

Lab. No.	Depth to which taken.	Water.	Sodium Carbonate.	Sodium Bicarbonate.	Sodium Chloride.	Sodium Sulphate.	Total Injurious Salts.	CROPS.
	Cents.	%	%	%	%	%	%	
126	0 to 15	5.79	0.053	0.231	0.057	0.062	0.403	1900, Samar; 1901, Cotton; 1902, Helba.
127	0 to 15	9.05	0.106	0.252	0.258	0.104	0.720	1900, 1901, 1902, Samar.
128	0 to 15	5.03	0.172	0.294	0.358	0.177	1.001	1900, Samar; 1901-1902, not cultivated.
129	0 to 15	4.80	Nil	Nil	0.014	Trace	0.014	1900, Samar; 1901, Cotton; 1902, Wheat.
185	Surface	12.92	0.159	0.840	0.775	0.931	2.705	No cultivation.

TABLE VI.—EFFLORESCENCES.

Lab. No.	Sodium Carbonate.	Sodium Bicarbonate.	Sodium Chloride.	Sodium Sulphate.
	%	%	%	%
182	22.26	10.25	10.55	17.81
186	0.53	3.15	19.81	24.81

2. THE SECTION NORTH OF THE ISMAILIA CANAL FROM ABBASSA KASSASSIN.

This is quite a narrow strip of land, and hardly to be distinguished from the adjoining desert, except here and there where some attempts have been made to cultivate a few small patches. At Tel-el-Kebir, however, there is a plantation of young trees belonging to the Government which occupies about 300 feddans.

The low-lying portion immediately bordering the canal is impregnated with salt which frequently comes to the surface as a white efflorescence. This is well shown on Plate XI which is from a photograph of a stretch of low ground situated between the Ismailia Canal and the railway near Tel-el-Kebir, the efflorescence being due to the rise and subsequent evaporation of the seepage water from the canal. A sample of this efflorescence from Tel-el-Kebir was examined and gave the following results:—

TABLE VII.

Lab. No.	Sodium Carbonate.	Sodium Bicarbonate.	Sodium Chloride.	Sodium Sulphate.
	%	%	%	%
187	Nil	1.68	6.60	32.91

3. THE PORTION OF THE VALLEY BETWEEN KASSASSIN AND ISMAILIA.

Kassassin is the termination on the east of the Wadi Estate, and here owing to a difference in levels the drainage-water has to be pumped from one section of the main drain to the section adjoining. The composition of this water at the pumping station, so far as salts harmful to agriculture are concerned, is shown on Table XIII.

About five kilometres east of Kassassin the drain enters Lake Mahsama, through which it flows, being discharged again at the other extremity of the lake, and continuing east passes under the Suez branch of the Ismailia Canal near Nefisha, and finally empties itself into Lake Timsah to the south-west of Ismailia.

Several samples of this drainage-water were taken at various points east of the pumping station at Kassassin, the results of their examination being given in the following table:—

TABLE VIII.
(Parts per 100,000.)

Date.	Lab. No.	Place from which taken.	Total Matter in solution.	Sodium Chloride.	Sodium Sulphate.	Sodium Carbonate.	Sodium Bicarbonate ¹ .	REMARKS.
Jan. 15	5	Lake Mahsama North side.	106·4	40·19	25·45	Nil.	63·84	
„ 15	6	Drain where it leaves Lake Mahsama.	102·4	36·89	26·06	Nil.	62·16	
„ 15	7	Drain where it passes under Suez branch of Ismailia Canal.	105·2	35·59	25·09	Nil.	60·48	
„ 15	8	Drain where it enters Lake Timsah.	102·0	39·04	26·06	Nil.	60·48	
„ 16	9	Lake Timsah	5375·2	1492·66	..	Nil.	22·68	Lime 34·0 per 100,000 Magnesia 298·76 per 100,000 Sulphur Trioxide 313·68 per 100,000

On comparing the above figures with those on Table XIII, it will be seen that the composition of the water does not differ materially

¹ Sodium bicarbonate on drying loses water and carbon dioxide and is converted into sodium carbonate, hence in the total matter in solution it would be weighed as 40·28, 39·22, 38·15, 38·15, and 14·30 parts respectively of the normal carbonate.

between Kassassin and Ismailia, and hence the channel serves simply to convey the drainage water to Lake Timsah, and does not act as a drain for that section of the wadi lying east of the pumping station.

Between Kassassin and Ismailia a large part of the valley is uncultivated, the surface for the most part being covered with sand and gravel, near Nefisha however the gravel practically ceases and is replaced by fine sand.

South and south east of Lake Mahsama, also between Abu Suair and Nefisha north of the railway, and south of Nefisha between the Suez branch of the Ismailia Canal and Lake Timsah are salt pools and considerable areas of marshy ground.

The east end of the valley, however, is not altogether barren, for it includes some comparatively large areas of cultivation and great number of small isolated cultivated patches.

“Near Nefisha station, and close to the place where the fresh-water canal to Suez branches off from the main Ismailia Canal, there occurs a greyish marly clay which is made into bricks by the Arabs. This is possibly an old lake bottom, but no shells are to be seen in the workings. Around Ismailia there is a good deal of low-lying ground which has been planted with palm-trees, etc., and which is possibly the filled up part of Lake Timsah. On the skirts of the palm-grove is a piece of marshy ground which has a good deal of salt in it, but its connection with the present lake is obscured by a number of dunes of blown sand. Further out in the desert an opening has been made for the purpose of digging out clay for brick making. This clay is a black, stiff clay which looks like that deposited in lakes. It does not extend far into the desert, and is in all probability connected with the marshy ground nearer Ismailia.

“There is plenty of evidence to show that the lakes covered much more ground formerly than at the present time. There is a good bit of marshy ground near Nefisha station which is shown in old maps as an arm of the Lake Timsah.

“The south-west shore of Lake Timsah is fringed with sand-dunes.

“Among these dunes numerous pools of brackish water occur.”

“Except for a few shells and shell-fragments, the sand of these dunes is all quartz.

“The country between the Wadi Tumilat and Bir Menaif is all submerged beneath blown sand, this sand also stretching westward along the south side of the Wadi Tumilat to the neighbourhood of

¹ Extracted from a manuscript Report by T. Barron, F.G.S., Survey Department, Cairo.

Tel-el-Kebir. In places this sand rises to form low dunes, and beneath the steep leeward slopes of many of these dunes is a muddy deposit impregnated with salt; similar deposits were observed in similar positions in the blown sand near Kassassin."

A sample of the surface soil and several samples of the efflorescence from this section of the Wadi were examined for harmful salts with the following results:—

TABLE IX.

Lab. No.	Nature of Sample.	Place from which taken.	Sodium Carbonate.	Sodium Bi-carbonate.	Sodium Chloride.	Sodium Sulphate.
			%	%	%	%
10	Efflorescence ...	Mahsuma ...	7.95	3.99	1.15	9.65
11	" ...	" ...	6.62	1.68	0.86	9.43
12	" ...	Nefisha ...	Nil	0.84	1.72	24.74
13	Surface Soil ...	" ...	Nil	Trace	Trace	Trace

NATURE AND EFFECT OF THE INJURIOUS SALTS.

From the analyses of various samples of efflorescences, soil, and drainage-water, the results of which are given in Tables V to IX and XIII, it will be seen that the harmful salts present in the Wadi Tumilat are: sodium carbonate, sodium bicarbonate, sodium chloride and sodium sulphate.¹ These salts, however, are not all equally injurious. Sodium carbonate, as would be expected from the fact that it is a fairly strong alkali, is the most harmful to vegetation, and has a marked corrosive action upon the plant tissues.

"Sodium carbonate has also a very injurious effect upon the physical condition of the soil when the soil contains clay, causing it to shrink in bulk, become extremely sticky, and dry into a stony mass. The presence of 0.08% of sodium carbonate in a heavy soil is sufficient to make it quite untillable."²

Sodium bicarbonate is considerably less harmful than the ordinary carbonate. This fact is clearly brought out in Table V. In sample

¹ The analyses are reported in the usual conventional manner: the alkalinity to phenolphthalein is calculated as sodium carbonate, the alkalinity to methyl orange, after neutralizing the sodium carbonate, is calculated as sodium bicarbonate; the whole of the chlorine is shown as sodium chloride and the whole of sulphates as sodium sulphate.

² "Physical Properties of Soil," Warrington, 1900, p. 214.

No. 126 sodium carbonate is present to an extent that alone would just begin to injuriously effect the growth of plants, while sodium chloride and sodium sulphate are not in sufficient quantity to be harmful. There is, however, 0.23% of sodium bicarbonate present, and yet for three years in succession crops were grown. Now since 0.23% of sodium carbonate would be fatal and of sodium chloride would be harmful, it follows therefore that sodium bicarbonate cannot be nearly as injurious as the normal carbonate and not more harmful than sodium chloride. Sample No. 127 brings out the same fact. In this case the amount of the normal carbonate is almost sufficient without the comparatively high percentages of chloride and sulphate also present to account for the soil being only capable of growing Samar. Again therefore the bicarbonate cannot be very harmful or the amount present, namely 0.25%, added to the 0.46% of the other salts would have effectually prevented the land from growing even Samar.

T. H. Kearney, of the U. S. Department of Agriculture, has recently arrived at the same conclusion by direct experiment, and states as a result of his work that "sodium bicarbonate proved to be somewhat less toxic than sodium chloride."¹

It must not be forgotten, however, that under certain conditions sodium bicarbonate becomes wholly or in part converted into the normal carbonate, hence, although not directly very injurious, it may very readily become so, and must therefore be regarded, at any rate, as potentially a harmful salt. The proportion of sodium bicarbonate that is changed into sodium carbonate increases as a rule with increase either of concentration or of temperature, and at 100° C. the whole of the bicarbonate becomes converted into the normal carbonate.

Of the sodium chloride and sodium sulphate the latter appears to be more harmful although on this point there is some difference of opinion.

Warrington states² "plants appear to be more tolerant of sodium sulphate." Stewart found³ that sodium chloride was more injurious than sodium sulphate to germinating seeds of legumes and cereales, and Loughbridge states⁴ that "sulphate of soda is hurtful only when present in very large amount." Means and Gardner state⁵ that "sodium

¹ Report No. 71, U. S. Department of Agriculture, p. 21.

² "Physical Properties of Soil," Warrington, 1900, p. 214.

³ Ninth Ann. Rep. Utah Agr. Exp. Stn., p. 26 (1898) quoted in U. S. Department of Agriculture, Report No. 71, p. 21.

⁴ University of California College of Agriculture, Bulletin No. 133, p. 42.

⁵ U. S. Department of Agriculture, Report No. 64, p. 56.

chloride is the most harmful to plants." Kearney, however, found¹ that for white lupin sodium sulphate was more harmful than sodium chloride.

The order of toxicity as given by Kearney, beginning with the most harmful, is: magnesium sulphate, magnesium chloride, sodium carbonate, sodium sulphate, sodium chloride and sodium bicarbonate.¹

The limits of concentration permitting the roots of white lupin to retain their vitality during twenty-four hours is as follows:—¹

TABLE X.

NAME OF SALT.	Parts per 100,000 of solution.
Magnesium sulphate	7
" chloride	12
Sodium carbonate... ..	26
" sulphate	53
" chloride	116
" bicarbonate	167
Calcium chloride	1377

The order of toxicity of magnesium sulphate and magnesium chloride is reversed by Coupin.² The minimum toxic concentration for sodium chloride, the same plant and the same method being used, is placed about three times as high by True.³

As a close approximation, however, of the limits of endurance for ordinary crops, the following table of values, compiled from the work carried out by the Division of Soils of the U. S. Department of Agriculture may be used.⁴ These figures are in close accord with the results of analyses of alkali soils in Egypt.⁵

¹ U. S. Department of Agriculture, Report No. 71, pp. 21, 54 and 19 respectively.

² *Rev. Gén. de Bot.*, 10, 188 (1898) quoted in U. S. Department of Agriculture, Report No. 71, p. 19.

³ Amer. Journ. Sci. ser., 4, 9, 187 (1901) quoted in U. S. Department of Agriculture, Report No. 71, p. 20.

⁴ U. S. Department of Agriculture, Report No. 64, p. 56.

⁵ "A Preliminary Investigation of the Soil and Water of the Fayum Province." Survey Department, Egypt, 1902.

TABLE XI.

Sodium carbonate	{ 0.05 per cent minimum danger line. 0.10 per cent maximum limit for growth.
Sodium sulphate and Sodium chloride	{ 0 to 0.25 not harmful. 0.25 per cent to 0.50 per cent harmful but not sufficient to prevent growth. 0.50 per cent maximum limit for growth.

The limit of endurance of plants for the various harmful salts is dependent not only upon the kind of salt present but varies also with the kind of plant, the age of the plant, the nature of the soil and the kind and extent of other salts present.

Of the crops ordinarily grown in Egypt the most resistant to alkali are Samar, Dinéba,¹ and Rice. Date-palms are also very tolerant of injurious salts.

Samar.—From observations made in the Wadi Tumilat and in the Fayum, in both of which places Samar is cultivated, this crop would appear to be one of the most resistant.

Dineba.—"With 2 per cent of salt in the soil a fair crop of Dineba two feet high can be grown ; with 1 per cent it attains its full height of four feet."²

Rice.—This is less hardy than Dineba.

Date-palms.—"In the Sahara date-palms will grow on land containing as much as 3 per cent of alkali."³

The age of a plant also conditions its susceptibility to injurious salts, the younger a plant the more susceptible it is to all adverse conditions, including the presence of alkali.

The amount of alkali tolerated by various cultures varies also with the nature of the soil, being lowest in heavy clay soils and highest in sandy soils.

The modifying effect that other salts have upon the degree of toxicity shown by any one salt when present alone has been brought out in a most marked manner by a series of experiments made by T. H. Kearney, who states that "the addition of a second less toxic

¹ *Dineba*, *Panicum crus galli* a species of millet.

² "The Reclamation of Lake Abukir," by H. E. Sheppard. Minutes of the Proceedings of the Institute of Civil Engineers, London, quoted in "Egyptian Irrigation" by Sir W. Willcocks, 2nd Edition, 1899, p. 251.

³ U. S. Department of Agriculture, Circular No. 9, p. 13.

salt in most cases increases the concentration of solution of the more harmful one in which root-tips can retain their vitality.”¹

The following table shows clearly the modifying effect of calcium sulphate and calcium carbonate :—¹

TABLE XII.

SALT.	Parts per 100,000	
	Pure solution.	In the presence of excess of calcium sulphate and calcium carbonate.
Magnesium sulphate	7	2240
„ chloride	12	960
Sodium carbonate	26	156
„ sulphate	60	2160
„ chloride	116	1160
„ bicarbonate	167	417

CAUSE OF DETERIORATION.

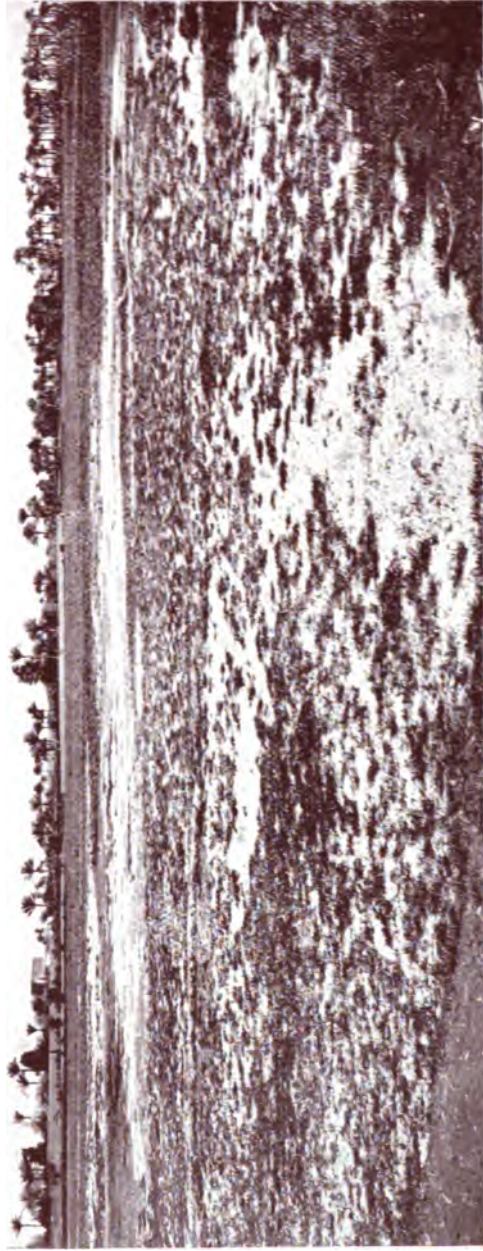
The ruin of the Wadi Tumilat was brought about by the construction of the Ismailia Canal, which was completed in 1863.

This is a high-level canal passing through a porous soil, and the leakage of water from it must be enormous. This seepage water percolating on the adjoining lands raised the general level of the sub-soil water, in places water-logged the soil, and everywhere within reach brought to the surface the injurious salts that were formerly at a sufficient depth to be out of the way of the roots of the crops, and so harmless.

The canal, however, only made manifest what had been taking place for centuries past ; it did not import into the valley the injurious salts ; these had been accumulating ever since the Wadi ceased to have a natural drainage outlet.

The soil contains calcium carbonate (carbonate of lime) and calcium sulphate (gypsum) together with sodium chloride (common salt). Any water entering the valley from the Nile would also contain sodium chloride (see Table XIV). Each year there would always be a slight rainfall (see Tables I and III). The sodium chloride in the soil would be dissolved, and as the water evaporated a strong solution of this salt

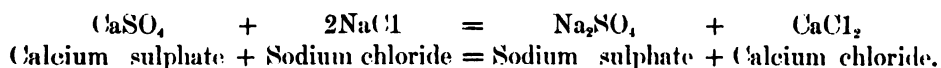
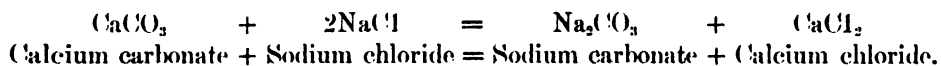
¹ U. S. Department of Agriculture, Report No. 71, pp. 41, 19 and 38 respectively.



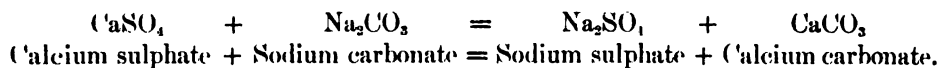
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BEFORE RECLAMATION.

would result. This would act upon both the calcium carbonate and the calcium sulphate with the formation of sodium carbonate, sodium sulphate and calcium chloride. These reactions in their simplest form may be represented as follows:—



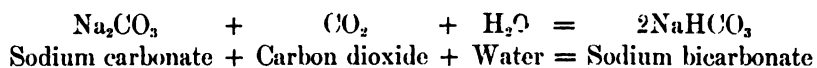
The formation of sodium carbonate would probably be lessened and the production of sodium sulphate increased by the action of the calcium sulphate upon the sodium carbonate thus:—



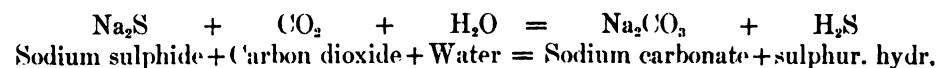
This reaction is sometimes made use of in the United States for the reclamation of lands containing sodium carbonate, calcium sulphate (gypsum) being employed as an antidote, with the result that the very injurious sodium carbonate is wholly or partly converted into the less harmful sodium sulphate.

In California the reclamation of lands made barren by sodium carbonate has been carried out for a number of years, gypsum being applied, turned under and thoroughly watered. "The result has been a very general conversion of the dreaded sodium carbonate into the far less harmful sulphate, and in spots where not a blade of grass would previously grow there have been produced excellent wheat and barley 3 or 4 feet high and full headed."¹

Sodium bicarbonate would be formed also by the action of carbon dioxide and water upon the sodium carbonate, thus:—



A portion of the sodium bicarbonate would however revert under certain conditions, forming the normal carbonate again. Sodium carbonate might also be produced by the reduction of sodium sulphate to sodium sulphide, as for instance by the action of bacteria, and the subsequent conversion of the sulphide so formed into a carbonate, thus:—



¹ University of California, College of Agriculture, Bulletin No. 133, p. 8.

The calcium chloride formed in the above reactions being extremely soluble would be removed much more rapidly by any slight drainage that might exist, or it would be carried deeper down into the subsoil than the other salts formed at the same time. Thus the calcium chloride would escape and sodium carbonate, sodium bicarbonate and sodium sulphate, together with a portion of the original sodium chloride, would remain. All these salts undoubtedly existed in the soil at the time the Ismailia Canal was made, but they were then brought either to the surface or within reach of the roots of the crops by the infiltration water from the canal, and so the valley became barren.

The one great cause of all the mischief was lack of drainage in the first instance. It may be laid down as a general rule that there cannot be any excessive accumulation of injurious salts in land that is efficiently drained.

RECLAMATION.

The reclamation in the Wadi Tumilat, which is entirely confined to the Wadi Estate, has now been in progress four years with the most satisfactory results, the management being in the hands of the Inspector of the First Circle of Irrigation, in whose district the Estate lies.

At the time the Estate was taken over much of the land adjoining the Ismailia Canal was swampy or actually under water, of the rest some portions were bare and covered with efflorescence, while others supported only rank grass, and less than one-third of the total area was cultivated. Of this cultivated land much was far from good, and, owing to the large amount of injurious salts present, bore only the poorest of crops. Since 1899, however, the main drain has been enlarged and re-modelled, branch drains, field drains and field channels have been dug, and the irrigation system improved. As a result the good land has become better, the poor land is now good, and the former uncultivated area has been diminished by one-half. The condition of the land before reclamation and the methods employed are well illustrated in Plates XII, XIII, and XIV. Plate XII shows a large area bordering the cultivation before being reclaimed and in such a bad state that nothing but a little rank grass will grow. Plate XIII shows a similar area about to be reclaimed and in which the field channels and small drains have already been made, while Plate XIV shows another plot where washing has commenced and where some of the salt at any rate has manifestly been transferred to the sides of the drainage ditches.



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ABOUT TO BE RECLAIMED.

The amount of reclamation effected can best be judged by the increase in the area leased for agriculture.

¹The figures are :—

1898	6,917 feddans.
1899	7,578 „
1900	9,382 „
1901	12,337 „
2 { 1902	15,200 „
1 { 1903 estimated... ..	17,500 „

From March to December, 1902, samples of the drainage-water from the pumping station at Kassassin were examined periodically. The following are the results obtained :—

TABLE XIII.—DRAINAGE WATER.

(Parts per 100,000.)

DATE	Lab. No.	Total matter in solution.	Sodium Chloride.	Sodium Sulphate.	Sodium Carbonate.
9th March, 1902	52	116·8	45·71	25·82	Nil.
16th April, 1902	71	125·6	48·01	32·64	Nil.
1st June, 1902	107	120·0	50·39	35·68	trace.
21st June, 1902	117	131·2	59·77	40·79	„
24th August, 1902... ..	125	95·2	37·50	25·08	„
22nd September, 1902	132	80·0	29·85	23·01	„
24th October, 1902	146	87·6	33·29	22·28	„
22nd November, 1902	172	98·0	36·75	26·43	„
24th December, 1902	188	101·2	37·89	21·56	Nil.
24th January, 1903	14	119·2	53·96	33·73	„

For purposes of comparison the accompanying table is given showing the amounts of both soluble water and sodium chloride present in the Nile at Cairo, which differs very little from the water used for irrigation in the Wadi.

¹ Public Works Ministry Report, 1901, page 217.

² Figures supplied by the Inspector 1st Circle of Irrigation.

TABLE XIV.—NILE WATER AT CAIRO.¹

(Parts per 100,000.)

Total Matter in Solution.			Sodium Chloride.			Analyst.	REMARKS.
Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.		
20·47	13·61	16·89	2·87	0·35	1·11	Letheby.	One sample each month from June, 1874, to May, 1875.
29·20	12·20	18·59	6·60	0·23	2·23	Pollard.	Two samples each month from June, 1888, to May, 1889.
23·12	13·12	17·58	4·80	0·92	2·18	Droop Richmond.	One sample each month from March to September, 1891.

It will be noticed that the proportion of salts washed out of the soil by a given volume of water varies very much with the time of year, being highest when the Nile is low and gradually declining with the rise of the river and the increase in the amount of water available.

The total amount of salts removed from the land however is probably greatest from August to November, since more water being available more will be used and more washing will be done, while during the rest of the year, irrigation is the chief business and washing a secondary consideration, and it is simply the concentration and not the total amount of salts that is the greatest in the drainage-water at the time of low Nile.

The average for ten months is 107·4 parts per 100,000 parts of water, and taking 17·7 parts per 100,000 as the mean of the soluble matter in the water supplied (Table XI) there remains a total of 89·7 parts of soluble matter derived from the land for every 100,000 parts of water drained away, that is, every cubic metre of drainage water carries away 0·897 kilo. of soluble matter, the greater part of which consists of injurious salts. "Unfortunately there are no records of quantities pumped,"² and so the total amount of salt got rid of cannot be stated, nor can any estimate be formed of the actual rate at which the amelioration of the land is proceeding.

An aqueous solution of mixed salts such as the Wadi Tumilat drainage-water is constantly undergoing changes in its composition, the individual salts acting and re-acting upon one another in such a manner that at no two consecutive moments will the exact combination

¹ Contributions to the Chemistry of River water, by H. Droop Richmond.

² Public Works Ministry Report, 1901, p. 217.

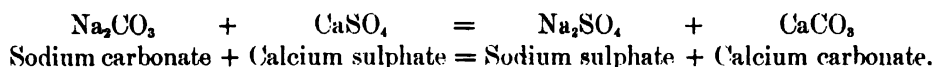


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UNDER RECLAMATION.

be the same, the results being dependent upon physical conditions that are always changing. Equilibrium at any given moment is conditioned by the concentration and temperature of the solution and by the amount of carbon dioxide present in the water or that can be taken up from the atmosphere.

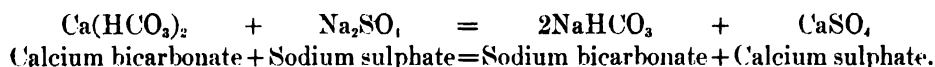
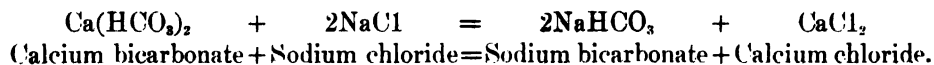
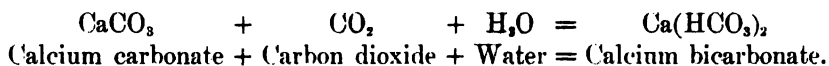
Although the drainage-water when tested never contained more than a trace of sodium carbonate and sometimes none at all yet this does not prove that no sodium carbonate whatever has been removed from the land, probably a considerable amount has been washed out, but, acting upon the calcium sulphate present it has been destroyed with the formation of sodium sulphate and calcium carbonate thus:—



A part of the sodium carbonate would also be converted into sodium bicarbonate, and as such is found in the water.

Sodium bicarbonate would probably also be formed by the action of calcium bicarbonate upon both the sodium chloride and sodium sulphate present, the calcium bicarbonate having been produced by the action of carbon dioxide upon the ordinary carbonate.

These various reactions may be represented as follows:—



Thus the sodium carbonate washed out of the soil would not be found as such in the drainage-water, while the sodium bicarbonate in the water would be far in excess of that removed from the land.

All the samples of the drainage-water contained bicarbonates in considerable quantity.

The actual amount present was determined in several cases. Calculated as sodium bicarbonate the figures are :—

Page - 20 -

It will be seen therefore that the drainage water in the Wadi Tumilat is not nearly saturated with respect to any one of the injurious salts present.

From a consideration of this fact two points of practical importance arise, namely:—

First, can the same amount of work (i.e. washing the land and supplying the needs of the crops) be done with less water, or in other words, can the same amount of water be made to wash a larger area and to support more crops? and

Secondly, if water were scarce at any time or in any particular spot, would it be safe to use the drainage-water for irrigation?

With regard to the washing of the land the amount of soluble matter removed is not directly proportionate to the quantity of water used, but is more dependent upon the manner in which the water is applied, frequent washings with small quantities of water being much more efficacious than the application of more water fewer times.

So far as the supply of water for the growth of crops is concerned, while fully recognizing that on an ample supply of water in a climate such as that of Egypt, more perhaps than on anything else, depends the quantity of the produce, and that the largest crops can only be grown with a wasteful consumption of water, yet it may be stated that the tendency of the Egyptian fellah is to use too much water.

Different plants require different amounts of water, and even the same plant needs varying amounts at different periods of its growth.

¹“In the earlier stages of leafy growth when the production of vegetable tissue is proceeding with the greatest vigour, the demand for water is greatest, and luxuriant growth at this period is largely determined by the quantity of water supplied. But in the later stages of seed production, when the transference of matter rather than its new formation is the great business of the plant, the presence of an excess of water is for many plants highly injurious and greatly diminishes the proportion of seed yielded by the plant. For seed formation therefore dry conditions are desirable.”

The fellahin, however, treat all crops at all times in exactly the same manner and apply as much water as they can get.

Certainly the maximum amount of soluble matter in the Wadi Tumilat drainage-water is very low, and this must mean either that too much water is being used or that the water is not doing all the work it is capable of in removing the injurious salts from the soil.

¹“Physical Properties of Soils,” Warrington, 1900, p. 90.

Whether any injurious effects are likely to follow the application of the drainage-water to the land as an exceptional measure in any special locality and for a limited period, would largely be conditioned by the efficiency of the drainage. The great danger would be the formation of the very harmful sodium carbonate, in places where it did not previously exist, by the separation of sodium bicarbonate from the solution and its subsequent conversion into carbonate.

In the Wadi Tumilat at least four different forces are constantly operative for evil, and it is against these that any reclamation work to be successful must make headway.

The evils are:—

(1) The constant seepage from the Ismailia Canal and its branches, with its attendant dangers of excessive sub-irrigation and the rise of salt from the subsoil towards the surface. That this seepage is really taking place at the present time is shown in Plate XV in which the efflorescent salts that have been brought to the surface by the rise of the seepage water are clearly marked.

(2) The descent from the higher desert lands on either side of injurious salts already present and likely to be brought down by every rain.

(3) The carrying by the wind of the efflorescent salts from the unreclaimed area and from the desert over the cultivated land.

(4) Sand encroachment.

To counteract the seepage from the canal and the drainage of injurious salts from the higher levels the remedies are the judicious use of irrigation water, deep drains and plenty of them.

Economy in the use of water is of vital importance in any region where injurious salts exist in excess in the soil, for two reasons:—

First, that there is great danger of the salts being brought to the surface or within reach of the roots of the crops by the rise of the level of the subsoil water, and

Secondly, that water applied to the land on a high level in excess of that required by the crops will drain on the lower lands carrying with it a large amount of harmful material.

This is very marked in the Fayum where the land slopes down towards the north-west from Medineh 22·5 metres above mean sea-level to Lake Qarun about 44 metres below mean sea-level.

“Throughout the Fayum the low lands are invariably sacrificed to the high. The level of the areas covered by efflorescences and of those places where the soil is either too bad to admit of any cultivation at



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BANK OF THE ISMAILIA CANAL.

all or else gives only the poorest of crops, is generally below that of the surrounding fields, and it is the drainage from the adjacent and higher ground, carrying with it an excess of injurious salts, that by percolating on the lower ground is the cause of the injury. Over-irrigation without corresponding drainage accentuates the evil. Every excess of water used for irrigating the higher lands beyond that actually required for the growth of the crops injuriously affects the lower lands.”¹

Good drainage, however, is the one remedy for all alkali lands.

The only method of preventing the efflorescences from being carried by the wind and distributed over the cultivated land is to reclaim as speedily as possible the present uncultivated areas.

With regard to sand encroachment, nothing can entirely prevent it, but with care the evil may be kept within narrow limits. Fences and the growth of perennial plants with widely spreading roots will do much to check the progress of sand.

GENERAL CONSIDERATIONS.

The manner in which the Wadi Tumilat was ruined is typical of the way in which other relatively low-lying lands in Egypt are also being ruined, though perhaps not on so large a scale, as, for example, in some parts of the Fayum.

Whenever a district is irrigated from a high-level canal without adequate provision being made for efficient drainage, invariably the low-lying fields will be converted into swamps, the general level of the subsoil water will be raised and the injurious salts will be brought to the surface.

“A good deal of injury has resulted to the low lands in the Fayum from the cultivation of the higher lands bordering the desert, as in many places these lands can be irrigated only by making channels in embankment across high ground, and in order to get the water on to the high ground a high level is maintained both in these channels and in the main canals which feed them.”²

The Wadi Tumilat may serve also as a type of the only way in which alkali lands can be reclaimed. There is but one remedy, and on the extent of the application of this depends the degree of fertility to which the land will ultimately be restored. The remedy consists

¹ “A Preliminary Investigation of the Soil and Water of the Fayum Province,” Survey Department, P. W. M. Egypt, p. 12.

² Report on the Administration of the Irrigation Department, 1895.

of thorough drainage and frequent washing. Drainage alone is insufficient, and washing without drainage is useless.

As supplementary aids to the restoration of the land to a satisfactory condition of fertility may be mentioned the special treatment by chemical or other means of those parts where sodium carbonate is known to occur in excess, and the cultivation in the first instance of plants that show a high degree of resistance to the particular injurious salts that are found to be present.

The chemical amelioration of alkali lands consists in the application of gypsum as described on page 387 ; other means are the addition and ploughing in of sand, carbonate of lime or lime. These methods are purely physical and act by making the clay more friable, more pervious to water, and hence more easily washed free from harmful salts.

In the reclamation of alkali lands, as in many other matters, much can be accomplished by rule-of-thumb methods aided by experience, but to obtain the best results in the shortest time and at the smallest cost the problem must be studied and solved on scientific lines.

A. LUCAS.

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